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Detecting holdover fires with the AGA Thermovision 750 infrared scanner

by J. Niederleitner

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DETECTING HOLDOVER FIRES WITH THE AGA THERMOVISION 750 INFRARED SCANNER

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ABSTRACT

Low intensity holdover fires are the cause of many damaging forest fires because they cannot be detected in time with currently available equipment and techniques. This report describes how an airborne AGA Thermovision 750 portable infrared scanning system over the course of one fire season detected 15 holdover fires for every 1 found by combined conventional methods, including cold trailing. Carried in regular patrol helicopters flying 100 m (300 ft) over areas susceptible to holdover fires, this off-the-shelf instrument was operated by fire line personnel as a component of the fire suppression operation. In-flight Polaroid or television recordings of the live, real-time, two-dimensional scanner display image can provide fire intelligence through heavy smoke for fire mapping and fire behaviour studies. The system costs approximately $35 000.

RÉSUMÉ

Les feux à retardement de faible intensité causent plusieurs incendies de forêts néfastes parce qu'ils ne peuvent pas être détectés à temps au moyen des instruments et techniques actuellement utilisés. L'auteur décrit ici comment un instrument portatif de balayage AGA Thermovision 750 par rayons infrarouges, utilisé par hélicoptère durant la saison des incendies a pu détecter 15 feux à retardement par rapport à un seul détecté par les méthodes classiques, incluant la vérification "manuelle". Cet instrument portatif fut placé dans les hélicoptères en patrouille régulière et volant à 100m (300 pi) au-dessus de régions vulnérables aux feux à retardement et il fut opéré par le personnel de ligne de feu tandis qu'il combattait

les incendies. Pendant le vol, les enregistrements par lumière polarisée ou par télévision des images actuelles "vivantes" et en deux dimensions fournies par cet instrument peuvent permettre de déceler les feux à travers la fumée épaisse en vue de cartographier les feux et d'étudier le comportement de l'incendie. Cet instrument coûte 35,000 dollars, environ.

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DEFINITION OF PROBLEM

Fire control agencies have identified undetected holdover or sleeper[1] fires as a major cause of damaging and costly forest fires. Most holdover fires, whether they are residual hot spots from prescribed burns or debris disposal projects, hot spots hidden near or outside a secured wildfire perimeter, or observed lightning strikes that went dormant, occur within predictably limited areas. Yet too often available detection techniques fail to find sleepers in their latent stage because there is not enough smoke or flame for visible detection, there are too many pieces of charred debris to be cold trailed, or there is not enough available surface heat to trigger the infrared line scanners now in use. (See Appendix.) As a result, surviving holdover fires often become active unexpectedly during dangerous burning conditions, and in many instances burn out of control before suppression forces can reach the site. An effective means of detecting these low-intensity fires is needed.

Traditional fire detection line scanners do not have the versatility and flexibility to detect holdover fires. The design and testing of these conventional scanning systems were based on target arrays of one to five braziers containing a 0.092-m^2 (1-ft^2) ash-free charcoal surface glowing at 600°C (1112°F), simulating the characteristics of a

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1 Also hangover fire. A fire that remains dormant for considerable time, or a fire that starts up again after appearing to be extinguished.

typical forest fire during the initial attack phase (Wilson et al. 1971). Even the most sophisticated traditional line scanner cannot reliably detect fires of lower intensity, but the typical holdover fire is of low intensity and also too elusive to be easily located by ground crews or aerial observation. It smolders persistently inside or underneath insulating materials, rarely surfacing, and unless smoking, offers only a little surface heat as a clue to its existence. To detect holdover fires an instrument must have relatively high sensitivity, possess the capability to work from a variety of ranges, and allow sustained observation of a point from a moving or stationary platform. Such an instrument would be employed to inspect typical problem areas, supplementing visual detection systems and high-flying infrared scanners.

Currently available off-the-shelf two-dimensional (providing a two-dimensional display comparable to a television set regardless of aircraft movement) infrared scanners, with their proven operational reliability, ease of operation, and remarkably flexible and sensitive live display can detect low-intensity fires under most circumstances. Two systems are available in Canada: the AGA Thermovision 680, a veteran dating back to 1965, and its new (1973) lightweight solid state counterpart, the AGA Thermovision 750 system[2].

Preliminary tests conducted in Alberta over the past few years proved both instruments very effective in detecting slightly heated areas;

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[2] The use of trade names in this report does not constitute or imply an endorsement of any particular product. It is merely a means of identifying a product having certain capabilities and qualities. Any other product offering similar properties can be substituted.

however, only the 750 system is portable and light enough for the intended application. This report describes the experience gained during one season's use of the Thermovision 750 system for detecting natural targets under wildfire conditions. The venture was a joint project between the Northern Forest Research Centre and the Alberta Forest Service.

DESCRIPTION OF THE AGA THERMOVISION 750 SYSTEM

The Thermovision 750 system is a battery-operated, portable, high quality, two-dimensional infrared scanner designed to be carried and operated by one person. The system consists of four major component units (Fig. 1).

COMPONENT UNITS

Camera

The hand-held camera contains a nitrogen-cooled indium antimonide detector, rotating prism, filter holder, interchangeable lenses [7° and 20° field of view (F.O.V.)], and aperture control. Except for the connecting cables, the whole unit resembles a super-eight movie camera (Fig. 6). The camera unit less lens weighs 1.5 kg (3.7 lb). The 20° x 20° F.O.V. lens weighs 0.18 kg (0.40 lb).

Display Unit

The display unit is carried on the operator's chest, held by a special harness. The unit's dimensions are approximately 130 x 250 x 320 mm (5.1 x 9.9 x 12.6 in.) and weight is 4.5 kg (10 lb).

All controls that need to be operated in flight are built into the display unit within easy reach of the operator (Fig. 2). These are:

1. The scanning temperature range and level setting
2. Isotherm display
3. Picture mode control (normal: black = cold, white = hot; inverted: white = cold, black = hot)
4. Gray scale adjustment
5. Photorecording adjustments

Recessed and shielded at the top of the display unit is the viewing screen, a picture tube 50 x 45 mm (1.9 x 1.8 in.) in size, which produces a continuous, live, real-time thermogram of the area scanned much like a television system (Fig. 3).

Power Pack

The Thermovision 750 system can be run from any 12-V DC car battery or 110-V AC house current power source. A factory-supplied leather-encased, portable, rechargeable battery weighing 3.6 k (8 lb) is available at extra cost. It operates the system for approximately 2 h.

For forestry work a heavy-duty power pack specially designed for such purposes was found more suitable (Niederleitner and Bihuniak 1976). It consists of a 20 A·h gel cell battery with built-in 12/24-V DC and 110-V AC 60-cycle chargers weighing approximately 15 kg (32 lb).

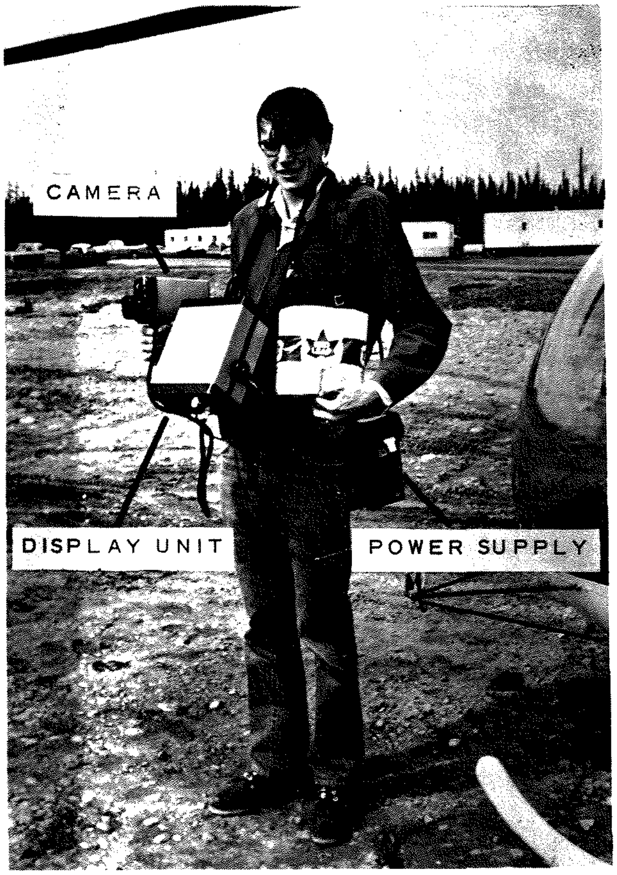


Figure 1. Components of an operational AGA Thermovision 750 system: camera, display unit, and factory-supplied power pack. Not shown is the photorecording unit. The toilet paper in the operator's hand was used for marking detected hot spots.

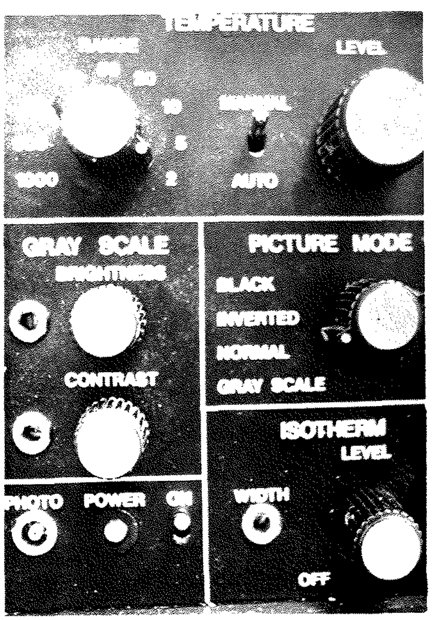


Figure 2. Controls on the display unit, which are located within easy reach of operator. No other controls need to be manipulated during flight.

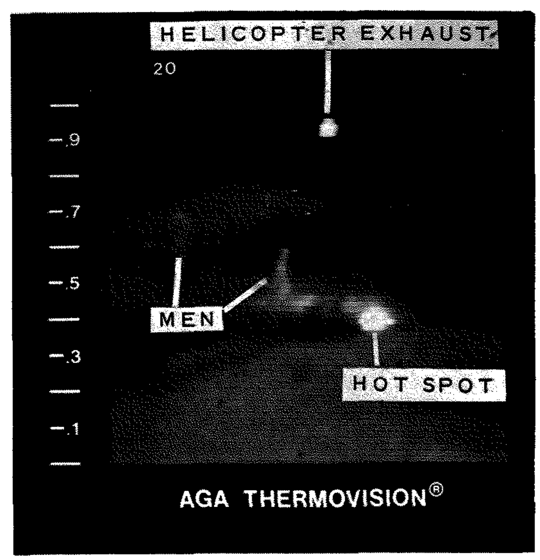


Figure 3. Thermogram of a natural hot spot missed by mop-up crew and found from the air. Temperature scanning range setting is 20°C. White hot spot near center of picture is much hotter than background, including the two men in the thermogram. White spot near top is the hot exhaust stack of the helicopter.

Photorecording Unit

A frame containing a flip-away mirror dovetails over the display tube. By flipping the mirror the picture is reflected from the eye-piece to a Polaroid camera with Type 87 black and white film pack. The photorecording frame allows viewing of the thermogram in bright light. (An adapter to connect a video recording system to the display unit is available).

PERFORMANCE FACTORS

Scanning Frequency and Detector

The Thermovision 750 system scans in the infrared band between 2.0 and 5.6 microns. Within this range the frequency response can be selected by means of filters. Heat radiation entering the camera unit through the germanium or silicon lens is reflected by a rotating scanning prism onto the indium antimonide detector located on the side of a small cooling dewar at the back of the camera, generating small pulses of current which are amplified and rearranged to show on the display screen as the pictorial thermal analog of the area scanned.

Detector Cooling

In order to function, the detector must be cooled to its cryogenic temperature of -196°C (-320°F). This is done by keeping the dewar filled with liquid nitrogen (LN_2) (Fig. 5). Loss of all the LN_2 from the camera dewar through spilling or natural evaporation causes the scanner to lose its temperature resolution temporarily; it does not damage the camera or any component.

In its present design the camera can only be pointed downward to approximately -70° from the horizontal without spilling an appreciable amount of coolant. Modifications on the dewar cover should make it possible to operate the camera unit in a vertical position. Normally, one filling of nitrogen lasts for 2 h.

Resolution

According to the manufacturer (AGA Infrared Systems 1973) the scanner can detect in each angular resolution element a minimum temperature difference of 0.2°C (0.36°F). This capability is referred to as temperature resolution. The angular resolution is expressed in milliradians, or mils (one-thousandth of a radian). Thus the smallest area a 1-mil system can resolve from a 300-m (1000-ft) elevation is 0.092 m^2 (1 ft^2). The angular resolution for the Thermovision 750 system is given as 1.1 mil for the 7° F.O.V. lens and 3.3 mil for the 20° F.O.V. lens. The temperature range that can be covered by the scanner is from -20°C (-4°F) to 2000°C (3632°F). Because of its high temperature and angular resolution a Thermovision unit flown low can detect ground fires through the slight rise in temperature in the overlying material caused by warm gases escaping from the zone actually burning.

Since radiation travels in a straight line the scanner must have direct line view of the object emitting the radiation. It must be operated through an open aircraft window, door, or hatch (Fig. 6) and aimed at the target area in such a manner that interference from standing timber and intervening debris is minimized.

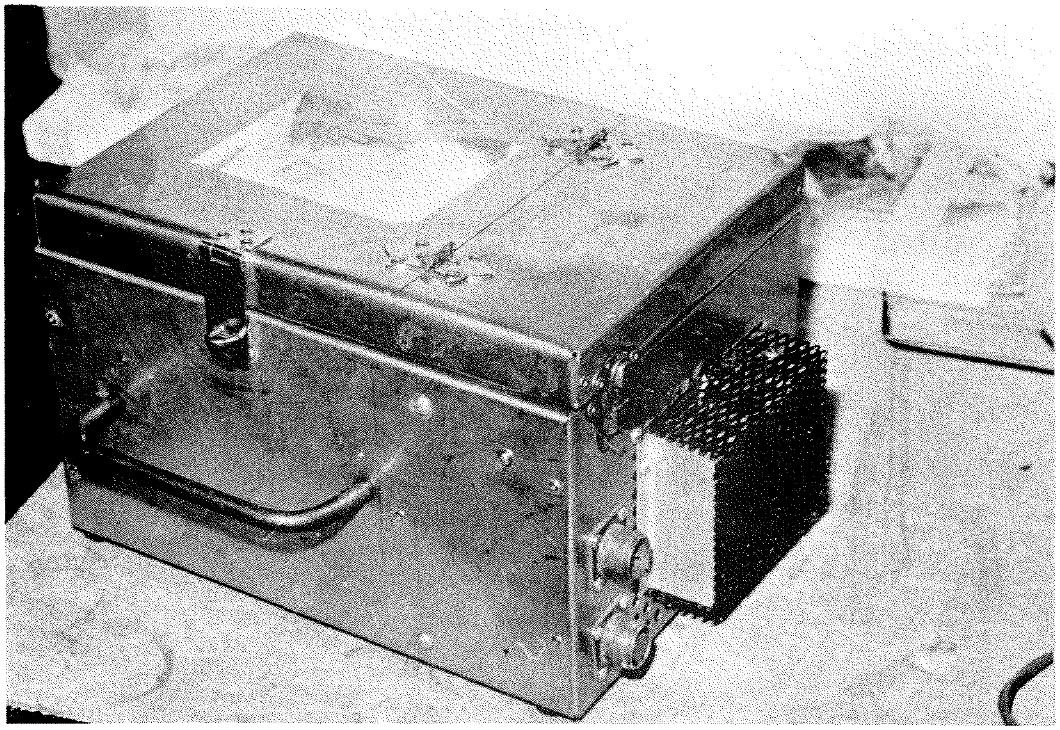


Figure 4. The rechargeable power pack developed at the Northern Forest Research Centre can operate the Thermovision 750 for a full working day.

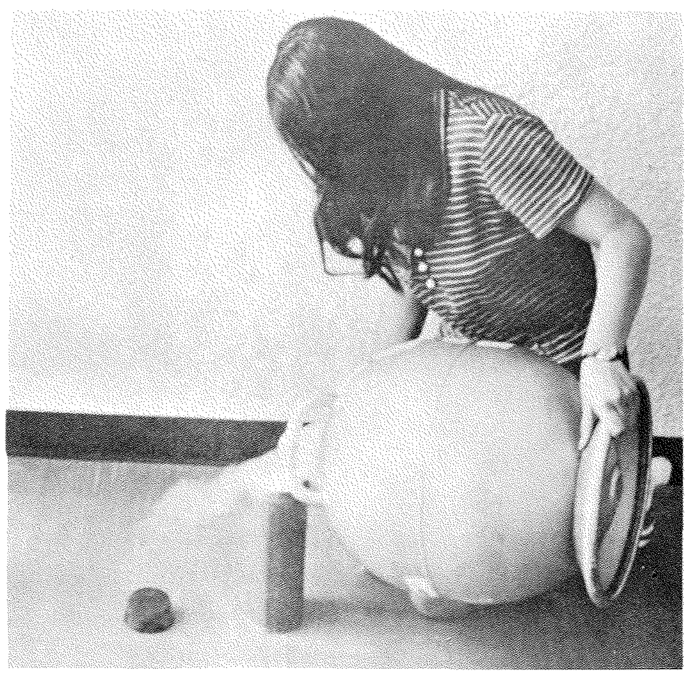


Figure 5. Liquid nitrogen storage containers. A 25-litre (5.5-gal) flask for storage at base and a thermos bottle for helicopter use.

Area of Coverage and Image Recording

Flying 100 m (300 ft) from a target using the 20° F.O.V. lens the area of coverage (Fig. 8) on the ground is approximately 30 x 50 m (90 x 150 ft), depending how far the camera is pointed down. Records of the live thermogram on the display tube can be obtained in the form of single Polaroid photographs or continuous recordings on television tape. Both types of recordings can be done in flight with specialized equipment by one person (Fig. 7).

Figure 6. Thermovision camera operated through the open aircraft window.

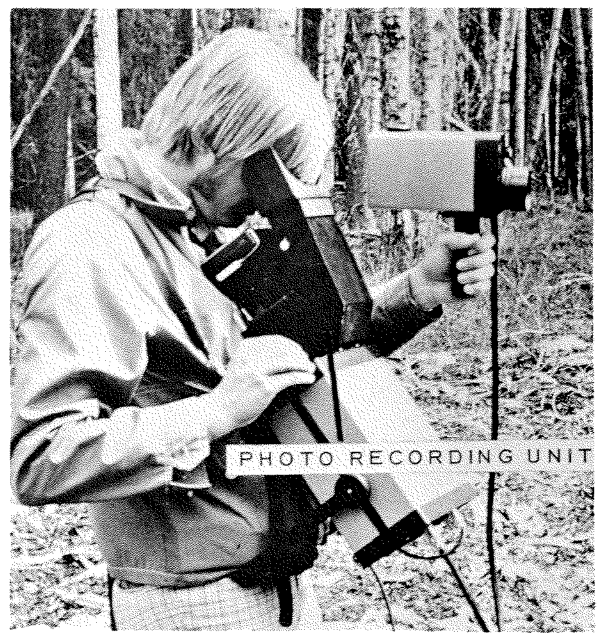
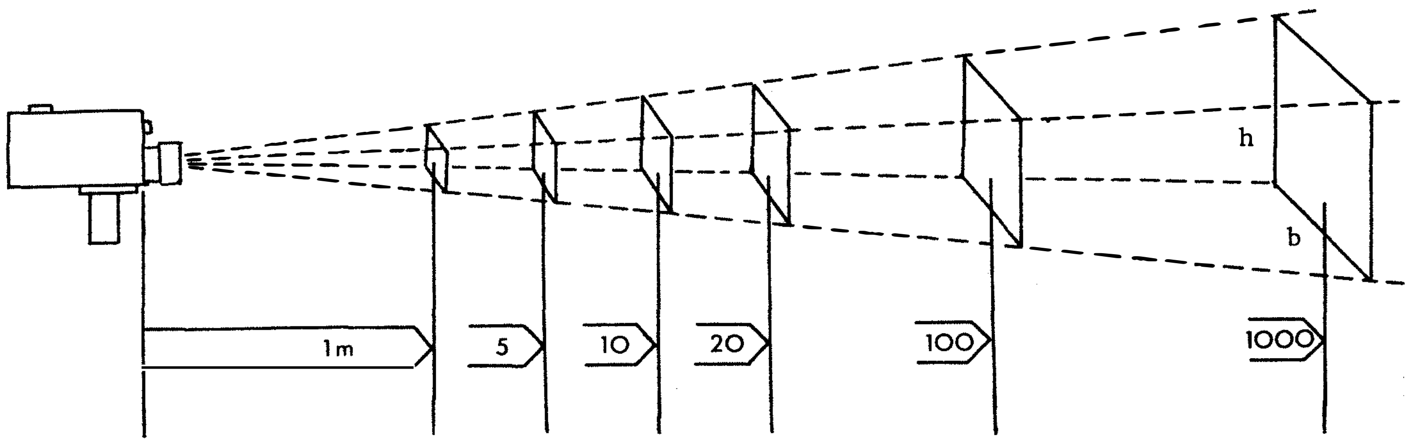


Figure 7. Photorecording. One person can operate both the scanner and the recording unit.



Field of view (in metres):

7^{o} lens:	b	0.11	0.60	1.1	2.2	12	120
	h	0.10	0.50	1.0	2.2	11	110
20^{o} lens:	b	0.35	1.7	3.5	7.0	36	360
	h	0.31	1.5	3.1	6.2	32	320

Figure 8. Field of view covered by the Thermovision 750 infrared scanner.

1975 OPERATIONAL TESTS

From the manufacturer's specifications and from our previous work with the Thermovision 750 we knew that the instrument could pick up faintly heated targets from a low-flying helicopter. Under ideal conditions it had picked up forest animals and the faces of fire fighters. However, a number of questions remained unanswered. Could the scanner, when used as an integral part of the suppression organization, find holdover fires that were now eluding detection? Could the AGA Thermovision 750 system be effectively integrated into an ongoing fire suppression operation without undue disruption? What were the problems in using the scanner on an operational basis? How and when should the instrument be used?

We leased an instrument from Agatronics Ltd. of Toronto for a 4-mon span to coincide with the fire season from May to September. The investigation was carried out jointly with the Alberta Forest Service which paid half of the instrument rental costs and provided air transportation and whatever assistance was needed at the target area. All work was done on natural hot spots and within the framework of normal suppression activity. Since helicopters are the principal fireline aircraft in Alberta, all work was done by helicopter. Scanning flights were conducted with whatever aircraft became available and the scanner was removed from the aircraft immediately after landing in order to release the craft for other work.

All inspections were done in the presence of the fire boss, line scout, or forest ranger who observed the screen on the display unit on the same flight on which he made his visual inspection. Thus the inspection covered the area of interest to the fire command and line personnel and eliminated any potential problems in communicating information for follow-up action.

The 1975 fire season was relatively mild and the operational opportunities to try the scanner were limited. Our first missions were intended to get the feel of the instrument and to develop suitable operating and search techniques. Although one man can operate the scanner we used two and three persons on most flights, mainly to expose as many people as possible to the scanner and its operation. Forty-three missions were conducted under vastly differing situations. Aircraft, pilots, and observers were changed frequently (Table 1). The work in the Whitecourt Forest in Alberta and in Newfoundland deserves elaboration.

WHITECOURT FOREST

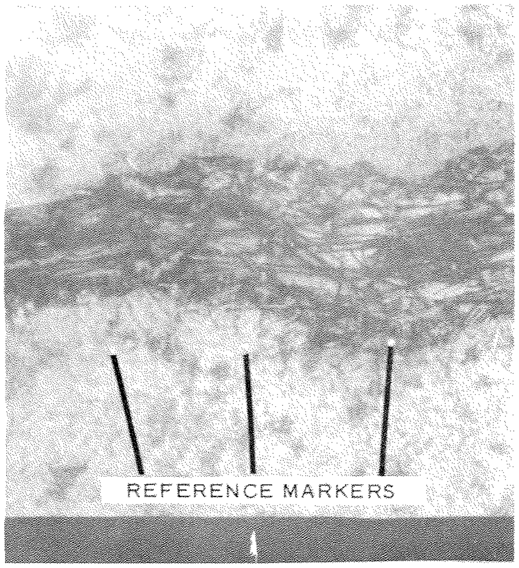
While waiting for calls to work on a fire, a small experiment was set up to practice with the scanner and to compare the scanner's capabilities against traditional cold trailing.

A recently burnt windrow at a land clearing project containing numerous hot spots appeared to be well suited for this purpose (Fig. 9). A stretch of windrow 150 m (450 ft) long was marked, measured, and cold trailed systematically in a 1.5 m (5 ft) grid pattern. Each of the 10 hot spots found was marked for easy visibility from the air. Eight of the spots produced visible smoke ranging in size from a cigarette's smoke to the smoke of a small campfire.

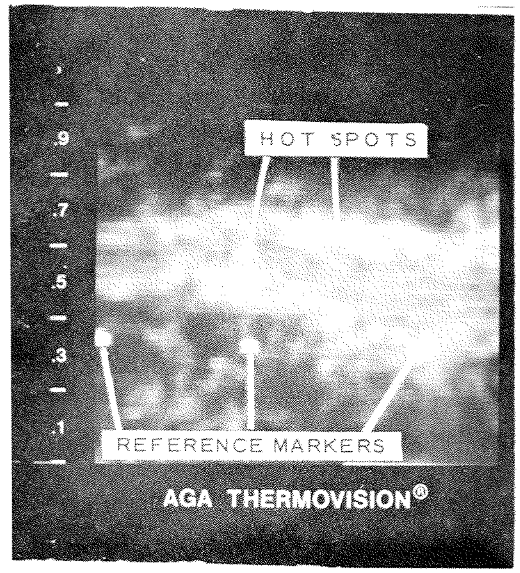
Table 1. AGA Thermovision 750 Utilization 1975

Province	Forest	No. of missions	Type of Assignment	Results	Remarks
Alberta	Whitecourt	5	Inspection of winter debris disposal burns Fox Creek, Fort Assiniboine.	Negative	Right of way clearings, nothing found, no fire reported at a later date.
"	"	4	Inspection of debris disposal burn along Western Construction road near Carson Lake.	Positive	Found numerous residual hot spots, verified on ground and checked to establish nature of holdover fires.
"	"	3	Inspection of burned-down brush piles for study purposes.	Positive	Found and documented numerous holdover fires.
"	Footner Lake	1	Checking fire boundary for residual hot spots.	Positive	Found holdover fire covered with dirt.
"	Slave Lake	2	Checking debris disposal burns along 20 miles of power lines and ten miles of road clearing.	Negative	Nothing found, no smokes reported during summer.
"	Lac La Biche	1	Demonstration - check garbage dump for hot spots.	Positive	Detected hard-to-see garbage fire, but some smoke was visible.
"	Edson	1	Demonstration on burned-down brush piles on ground.	Positive	Detected hot spots not emitting smoke.
"	Bow-Crow Forest	3	Demonstration, ground and air	Positive	Detected hot spot on garbage dump - but visible smoke.

Province	Forest	No. of missions	Type of Assignment	Results	Remarks
Alberta	Rocky Mtn. House	1	Demonstration on ground inspecting burned-down brush piles.	Positive	Detected hot spots not emitting smoke. Took video recording off scanner screen.
Newfound-land	Exploits	15	Inspection of 64 km (40 miles) of fireline for hot spots.	Positive	Located some 20 non smoking hot spots each morning to keep 140 men and 5 copters busy.
Alberta	Forestry Training School, Hinton	7	Inspection of 24-ha (60-acre) prescribed burn as part of training for 15 fire overhead trainees and two instructors.	Positive	Fire contained numerous hot spots, many still smoking. No hot spots outside fireline.
	TOTAL	43			



a.



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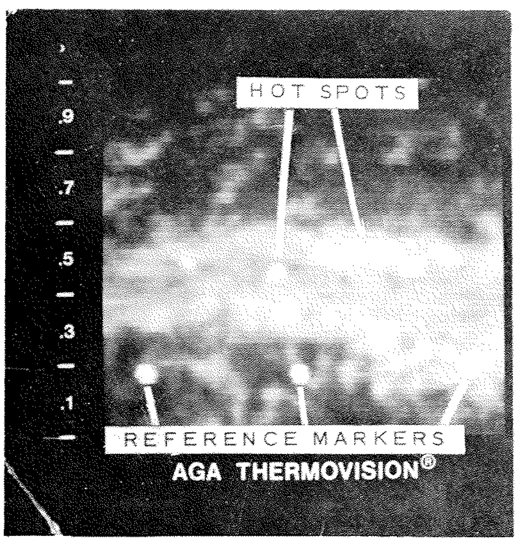

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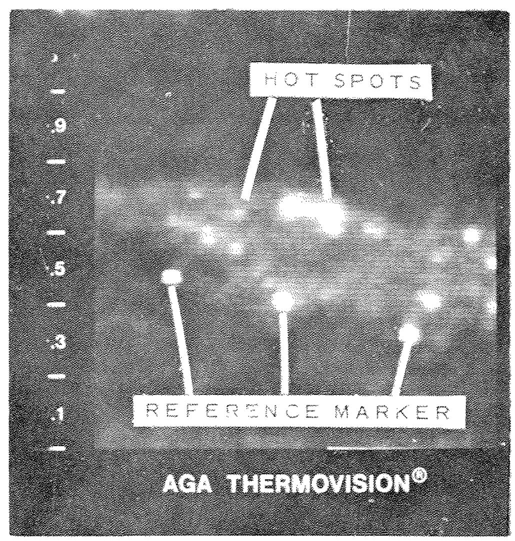

d.

Figure 9. Thermovision 750 test on a burnt windrow containing hot spots.

a. Black and white infrared film photographs of part of windrow.

b. Thermogram of same area from 33 m (100 ft) altitude.

c. Thermogram from same position after 1/2 h.

d. Thermogram from 50 m (150 ft) altitude of same area and with scanning sensitivity reduced to emphasize hot spots and block out background. The three evenly spaced spots at lower edge of windrow are reference markers [0.57-litre (1-pint) tin cans containing 2 glowing charcoal briquettes].

Flying over the windrow at an altitude of 30 m (100 ft) the Thermovision picked up 27 hot spots, 17 more than found by cold trailing (Fig. 10). Two additional flights spaced at 1/2-h intervals produced similar results (Fig. 11). A high overcast prevented the formation of sun-heated pockets in the debris. The angle of observation made no difference in the number of observed spots but seemingly shifted their location, probably the result of sensing the temperature of overlying material which was up to 0.5 m (2 ft) above ground and the parallax produced by the scanner camera slant of approximately -50°. Decreasing the flight altitude did not affect the number of hot spots counted, but when the altitude was increased some of the weaker spots began to disappear (Fig. 3d).

All of the hot spots were cooler on the surface than they were 15 cm (6 in.) below. Surface temperatures varied from 35°C (95°F) to 171°C (340°F). There was also considerable variation in the size of the heated area, ranging from 0.092 m^2 (1 ft^2) to 1.5 m^2 (16 ft^2).

A debris disposal project on a 24-km (15-mile) long road right-of-way through timber country in the Whitecourt Forest was the site of one of the first operational inspections. Sleepers were discovered in some of the burnt debris piles and a dozer was dispatched to disperse what was left of the piles. Ground crews cold trailed the remnants behind the machine. At inspection time 13 piles had been dozed and cold trailed. The scanner found hot coals missed by the ground crews in 9 of the treated piles. Because the weather was cool and damp the hot spots were marked for further inspection and left to go out by themselves. A lone spot lasted more than 1 wk (Figs. 10a, b, c, d). It was then put out to avoid further inspection trips.

NEWFOUNDLAND

The 11 000-ha (27 000-acre) "Exploits" fire in Newfoundland offered the opportunity to apply the scanner in support of a major mop-up operation. Some 64 km (40 miles) of irregular and winding fire boundary, interspersed with spot fires outside the fireline and incomplete burns, required patrolling.

Almost every day, sleepers located well inside and along the perimeter of the fire, flaring up in high winds toward noon, threatened to escape the thinly spread suppression forces. A means of detecting the sleepers in their dormant stage earlier in the day when they could be drowned out easily was needed. Each day the scanner, taken along on the fire boss's morning inspection flight, detected numerous hot spots. Approximately 20 (enough to keep the suppression crews busy for one day) were flagged with calculator paper, and the suppression crews following in other helicopters were directed to them by forestry radios. The paper flagging not only helped the suppression crews to locate the hot spots, but when ripped into shreds after the fire was extinguished, served as reference for subsequent inspection flights.

After a few missions a pattern of operating and search techniques evolved. Because most operators are right-handed, we pointed the camera

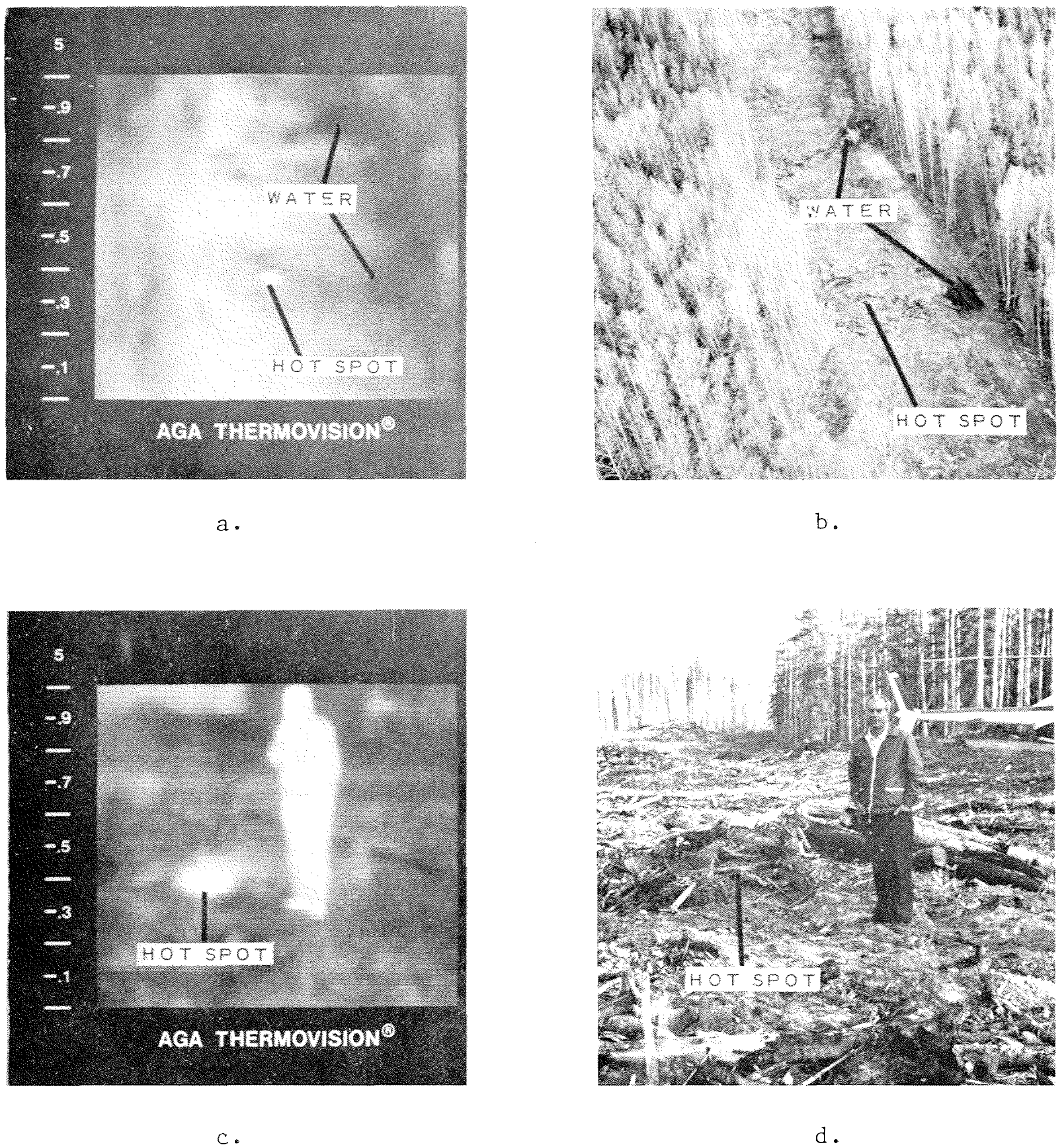

Figure 10. A sleeper missed by mop-up crews after 1 week of observation.

a. Sleeper on right-of-way clearing as seen from air.

b. Photograph of same area.

c. Same sleeper as seen on Thermograph on the ground.

d. Photograph of same area.

out through the left-hand helicopter door window at an angle of approximately -45°, leaving the right hand free to manipulate the controls on the display unit. The pilot would fly the helicopter slightly to the right of the target area at an altitude of approximately 100 m (300 ft) (Fig. 8). Helicopters are limited in the amount of hovering they can do in any one area so all targets were flown in one or more strips, and more time was spent on suspicious-looking spots. Each strip was flown at least twice in order to scan each spot from opposite directions. In addition, when the area to be searched was very large the camera was panned slowly back and forth. This increased the area of coverage and offered a better look under logs and debris or behind standing trees. To detect surface or ground fires under an intact dense canopy we found it advantageous to lower the camera angle to about -70° and to cover the priority areas with a series of spirals.

Early morning hours and cloudy days, with background temperatures within a very narrow span (from 2° to 5°C) proved to be the best time for inspection flights. Any unnaturally heated areas showed up like a burning lightbulb in the dark.

The most successful operating procedure for the inexperienced operator was to set the temperature level control to automatic and the temperature range control to the most sensitive value possible which did not produce blooming from background objects. With this setting any object only a few degrees warmer than the background bloomed brightly on the screen, making a target discrimination module or similar device unnecessary.

A rough temperature estimate of the hot spots was obtained by simply switching the range controls to progressively higher values. The longer the spot bloomed on the screen the hotter the target was. A more precise analysis of temperature values is possible by using the manual level control and the isotherm function (Fig. 2). This too is a relatively simple procedure.

A 0.57-litre (1-pt) thermos bottle filled with liquid nitrogen and the heavy duty power supply carried in the helicopter were found to be adequate for operating days in excess of 8 h. Although a 7° F.O.V. lens was available, the 20° F.O.V. lens was the one used most. The 7° F.O.V. lens is helpful if a warm spot a long distance from the copter requires close scrutiny. The telescopic effect of the lens obviates changing altitude, but because of the extra length of the lens aircraft vibrations are more noticeable.

RESULTS

Capability to Detect Hot Spots

Under the conditions encountered the scanner detected low-intensity holdover fires faster and more reliably than men on the ground or in aircraft. It consistently located approximately 15 hot spots for every 1 found otherwise (mostly smoking hot spots). More than 100 targets were located with the scanner during the season. There was no instance of a target showing visible smoke and the scanner not responding.

Integration into Existing Operational Organization

The scanner was successfuly integrated into all organizations in all situations without undue disruption. In many cases the scanning equipment was loaded or unloaded while the helicopter's engine was still running. With the scanner operator staying in the same locale as the helicopter pilots or in the main fire camp, no communications problems developed. Scanner missions were flown with nine different pilots, and 20 different observers operated the display unit, yet the objective of each mission was accomplished. The scanner was flown in Bell Jet Rangers (206B) and Bell 47AJ2 helicopters.

Angle of Depression of the Camera Unit

A flexible angle of depression of the camera unit was more convenient than a rigid vertical position. The oblique thermogram supplements the observer's visual impression, allows continuous comparison of the seen and thermal pictures, and permits more time to observe suspicious areas. It also makes it much easier to follow jagged fire boundaries and locate a hot spot on the ground after it has appeared on the screen.

Standing timber was found to be a considerable obstruction when scanning with line scanners at appreciable angles off vertical (Wilson et al. 1971). This problem is less apparent with a hand-held two-dimensional scanner because the camera can be pointed at will and the changing position of the helicopter offers access to the forest floor from many directions.

In many situations the slanted camera could reach underneath intervening material that obstructed vertical access to the heat source. Vertical operation using a rigid camera mount is feasible for high altitude work more than 1000 m (3000 ft) above ground.

Holding the Camera Unit

All mechanical mounts tried in helicopters resulted in some aircraft vibrations reaching the camera. Hand-holding proved to be the simplest, most flexible, and steadiest method of operating the camera. It made it easy to keep the camera on a target and establish the target's exact location and temperature range while the helicopter circled in a tightening spiral.

Taking Recordings

Aside from demonstration purposes or when there was no time to mark targets on the ground, photo or video records were found to be of limited value. Recordings are needed for fire mapping or fire behaviour studies, but these should be taken from higher altitudes. Photorecordings rarely ever did justice to the background detail visible on the live imagery. They showed only the small part of the area covered at the moment of exposure and seemed like words out of context. Video recordings caused problems in communicating the recorded information and in subsequent processing such as transferring to map or photomosaics.

a. b.

Figure 11. Video recordings.

a. Video recording of thermogram showing refuse dump with hot spots.

b. Video recording of same area from slightly different angle.

Flying Height

To locate and mark low-intensity hot spots precisely or to under-fly clouds the scanner must be flown as low as possible, yet high enough to cover enough territory to make the search meaningful. Most work in 1975 was done at an altitude of 100 m (300 ft). Flying at higher altitudes resulted in weak targets fading out and clusters of targets located close together fusing into one blob on the imagery.

Hot or flaming targets can be sensed by the scanner from great distances. For instance, a weak surface fire in a dense timber stand obscured by low-lying smoke more than 1000 m (3000 ft) away could be clearly seen on the scanner screen, yet the airtanker group flying low over the area to bomb the fire could neither see the flames nor observe the effect of their drops through the smoke.

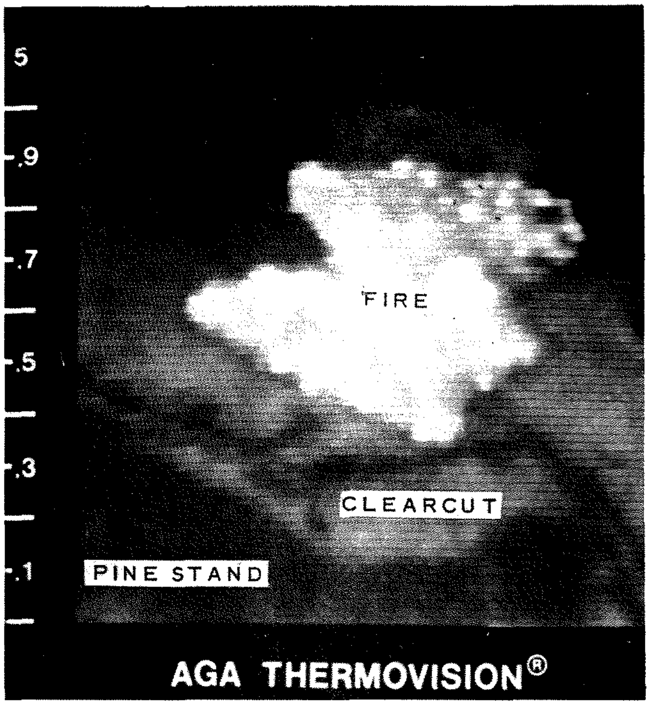

Figure 12. Fire mapping. Oblique thermogram of 24-ha (60-acre) slash disposal project taken from 650-m (2000-ft) altitude 2 days after burning with little visible smoke but much smoldering debris. All white areas are hotter than the normal background temperature of 6°C (43°F).

Coolant for the Detector

A 25-litre (5.5-gal) flask of LN_2 was kept ready throughout the season. One filling, costing approximately $50, lasted for 1 mon. A 0.57-litre (1-pt) thermos bottle was carried in the copter from which the camera dewar was filled in flight as required. LN_2 is available at most larger centers and is acceptable as air freight shipment.

Operating Reliability

No breakdown of equipment was encountered during the 4-mon season, nor was any adjustment or servicing of any component required. The scanner was shipped to numerous fire camps in Alberta and Newfoundland by public transporation, truck, car, and aircraft. At fire camps serviced by helicopter the scanner was exposed to heavy dust.

False Alarms and Interference

The Thermovision 750 system was equipped with the optionally available anti-solar reflection filter. This filter reduces but does not totally eliminate reflected sunlight. On rare occasions sun reflections off water bodies could be observed but were never mistaken for a fire.

No instances of interference by static, atmospheric disturbances, lightning, radio transmissions, or any other source were observed. Clouds, fog, or high relative humidity have little influence on the scanner's performance because it is operated very close to the target. The scanner was not bothered by picture tube saturations, afterglow, ghosts, trails, distortion or synchronization problems, excessive response lag, or similar occurrences common with television systems.

Resolution and Image

Because the thermal imagery consists of only 70 lines with 100 picture elements per line, it appears coarse when compared to a photograph. Yet, because each picture element is fairly large, the operator can quickly spot the few picture elements blooming out when a hot spot is found. The scanner's imagery is not susceptible to distortions common with line scanners.

The display screen showed sufficient background detail to allow continuous orientation over all areas other than those of vast homogenous vegetation cover such as even-aged pine stands. By observing on the thermogram changes of forest cover in respect to species, density, or height class, topographic features, moist or dry grass areas, clearings, rock outcrops, or water bodies, the operator could continuously match the seen world with the scanned area and precisely locate a hot spot on the ground as it appeared on the screen. The transfer of the location to a map was done in the same way as any other visually located feature.

DISCUSSION

Based on accumulated experience during a season's work under various operating conditions in the field, it can be said that an off-the-shelf AGA Thermovision 750 system hand-held and used to supplement visual observation is an effective air borne tool for detecting low intensity holdover fires that cannot be found by conventional methods or infrared line scanners. The system works best when the general location of the elusive fires is known.

The availability of a Thermovision 750 system will not only make if safer to abandon an extinguished fire, it will speed up mop-up work, make the job easier, and in cases of prescribed burns, may permit burning during periods that are now considered unsafe because of the risk of holdover fires.

Although no fires were mapped with the Thermovision 750 system [large fires were observed on the display screen and a 24-ha (60-acre) fire recorded] the instrument has the potential to collect and record fire intelligence through heavy smoke. By providing information on the perimeters, intensity, behaviour, and rate of spread of fires in smoke-obscurred areas, the Thermovision 750 seems to be an ideal mate for fire mapping operations based on infrared photography taken on site.

Airtanker and helitanker operations on large fires are usually condemned to idleness during the early morning hours -- when they could be most effective -- because either the lack of visible flames and smoke or the presence of obscuring smoke prevents detection of hot spots. A lead-in plane (probably a helicopter) with a Thermovision should be able to direct water or retardant drops more effectively during such periods as well as gain a better overview of retardant drop concentrations by using the scanner's capability to isolate cooled areas.

The Thermovision 750 system is well suited for use on wildfires by fire line personnel because of its simple operation and its real time clear-cut imagery that eliminates the need for handling or interpretation by third parties.

Radio links to and from the scanner aircraft can be used at all times, since the Thermovision is not, unlike most line scanners, affected by radio transmissions.

The AGA Thermovision 750 system is a precision instrument yet rugged enough to be taken to the fireline. It survived a season of rough fieldwork with no damage. Since the system is fully portable it can be quickly taken in and out of helicopters, releasing the helicopter for other work whenever required.

Cost for a complete Thermovision 750 system is estimated to be approximately $35 000. The system is manufactured by AGA Infrared Systems AB S-181 81 LIDINGÖ, SWEDEN, TELEX 17781 AGALIDS and distributed by:

AGATRONICS LTD.
41 HORNER AVE., UNIT 5, TORONTO 18
TELEPHONE 252-4691

The question of cost-benefit is difficult to answer. Assuming that the Thermovision has a life of 5 yr, the annual cost is $7 000 plus miscellaneous expenses. At our arrival in Newfoundland the Exploits fire had tied down five Bell 206B helicopters and some 140 men who had been playing cat and mouse with sleepers for more than three weeks. An operation of this type costs a good $10 000 per day. Would it be too much to assume that had the scanner been available from the start it would have saved four operating days and paid for itself?

RECOMMENDATIONS

The AGA Thermovision can and should initially be used in the field as it comes from the factory. If the scanner is to be used for low-intensity fire detection and fire mapping the following items are required:

1. Camera unit
2. Display unit

3. Power supply battery charger
4. 20° F.O.V. lens
5. Battery pack
6. Carrying harness
7. Open viewing hood
8. Long viewing hood
9. Camera hand grip
10. Photorecording unit
    a) Main frame with beam splitting channel
    b) Polaroid camera back
11. Tool set
12. Instruction manual
13. 25-litre (5.5-gal) or 10-litre (2.2-gal) nitrogen flask
14. Standard 0.57-litre (1-pt) thermos bottle
15. Heavy duty power pack per NFRC design (Niederleitner and Bihuniak 1976)

In addition we recommend the following:

1. 3-man portable aircraft intercom system
2. Holding brackets for camera and thermos bottle
3. Arrangements for back-up for the entire system at the time of purchase if a purchase is considered.

The installation of a monitor for the pilot and modification of the camera for vertical operation may be desirable. Arrangements for this could be made with the manufacturer at time of purchase.

Even a short (2-day) training session of the parties involved in the scanning operation, including the pilot, will pay in decreased time over target and increased reliability of the results.

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APPENDIX

REVIEW OF CURRENT EQUIPMENT AND TECHNIQUES

GROUND APPLICATIONS

Cold Trailing

The best known technique of finding low intensity hot spots is cold trailing. This method requires the men to feel every suspicious-looking spot with their bare hands.

Hand-held Infrared Detection Devices

A number of hand-held infrared sensors have been tried to simplify cold trailing. These instruments are basically radio meters that give an audible warning when pointed at a heat source exceeding a certain radiation intensity value. Some of the models field-tested were the DeHaviland Hotspotter, the Spar Aerospace Hotspotter, the Williamson Model 1207 Fire Detector, and an infrared heat detector Model 1175-1-1 of unknown manufacture. None of them were acceptable, mainly because of the instrument's narrow angle of coverage and relatively poor heat sensitivity.

AIRBORNE APPLICATIONS

Infrared Line Scanners[1] Designed for Forest Fire Detection and/or Fire Mapping

The United States Forest Service under Project Fire Scan developed and experimented with several infrared scanners that can detect forest fires from their high intensity heat radiation through heavy smoke, independent of visible light (Wilson et al. 1971).

The Barnes Airborne Fire Spotter (Kruckeberg 1971, Anon. 1970): This is the simplest, cheapest, and most popular scanner (over 40 units were commercially produced) that came out of the project. Instead of producing imagery or recordings of the scanned terrain, the scanner has a bank of lights that indicate in which scanning sector a high radiant energy source is located. By design this scanner should detect a 0.092-m^2 (1-ft^2) size target in the 600°C (1112°F) range from 750 m (2000 ft) altitude, but will not respond to the low surface heat produced by many holdover fires. The initial popularity of the Barnes spotter has declined because of the unit's susceptibility to frequent false alarms.

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[1] Line scanners record only one narrow strip of terrain at right angles to the aircraft axis at a time. The scanner depends upon the uniform forward movement of the aircraft to compile a two-dimensional picture by placing each newly scanned line ahead of the previous scan line similar to a continuous strip camera. In turbulent air or if the film transport is not perfectly synchronized with the aircraft speed the imagery can be badly distorted. This is the reason why line scanners cannot produce any meaningful imagery from a stationary position or from a meandering helicopter.

Availability: Originally an off-the-shelf item, but at this time out of production.

Cost: (in Canada, 1972) $3500

H.R.B. Singer Reconofax XI (Hirsch et al. 1968): This high quality line scanner, used mainly with a Polaroid recording unit, is basically a fire mapping tool. If flown low it should pick up fair-sized holdover fires, but we have no information to suggest that the Reconofax XI is capable of detecting low-intensity sleeper fires.

Availability: Made to customer's order.

Cost: (in U.S.A., 1972) approx. $100 000

Bispectral System (Wilson et al. 1971): The bispectral system is the most sophisticated infrared line scanning system developed through Project Fire Scan. It is a modified Texas Instrument, RS7 line scanner operating on two channels, designed to detect a 0.092-m^2 (1-ft^2) 600°C (1112°F) target from 5000 m (15 000 ft) altitude, equipped with near-real-time in-flight printout capability and a target discrimination module. It is suitable for fire detection flights over large areas as well as for mapping. However, even this scanner is of questionable value as a holdover fire detection tool, mainly because it requires the high radiant energy pulse as emitted by glowing material in direct line of sight to trigger the target discrimination module. In a paper summarizing the progress of Project Fire Scan, Hirsch et al. (1971) stated that "Fires too small to print on the image can be identified and located by ground crews."

Availability: Made to customer's order.

Cost: (in U.S.A., 1972) approx. $140 000

Fire Mapper: A Canadian manufacturer, Computing Devices of Canada, produced this infrared scanner which was tested in Ontario. As the instrument's name implies, the unit was meant to map going wildfires through smoke and had some fire detection capability (Computing Devices of Canada Ltd. 1965). The unit did not meet Ontario Forest Service expectations and is apparently not in operational use.

Availability: Not known.

Cost: (in 1972) approx. $40 000

Other Thermal Mappers

Many companies manufacture thermal line scanners and thermal mappers (Anon. 1974) capable of mapping or collecting information from going wildfires through smoke, but in order to use them for fire detection purposes, further development and modificiations similar to the work done under Project Fire Scan would be required.

Other Remote Sensing Systems or Devices

Various optical and electronic devices such as night vision goggles, infrared fire detector telescopes, and special filters for binoculars or spectacles have been tried as aids in fire detection with little success.

Some television systems are sensitive to radiation in the near infrared and the infrared spectrum. Recent tests with infrared television systems (Kourtz 1975, Kourtz and Pinson 1975) did meet with some success in imaging high radiant energy targets [a cluster of five 60-cm (2-ft) diameter charcoal buckets] at altitudes up to 1300 m (4000 ft) with a 10° field of view lens. While these tests show that infrared television systems have some potential no evidence was presented to support the conclusion that sleeper or holdover fires could be detected.